National Aeronautics and Space Administration

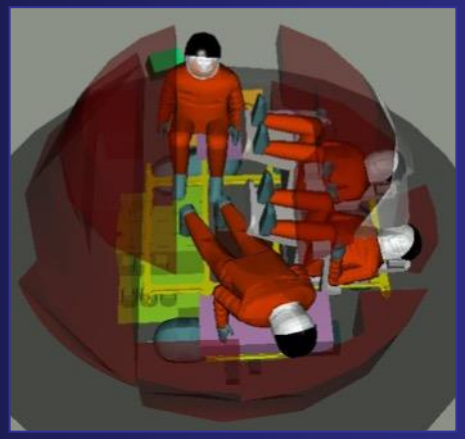
Human Research Program

Steven H. Platts, Ph.D.
Chief Scientist
Jancy Mcphee, Ph.D.
Associate Chief Scientist

humanresearch.jsc.nasa.gov

Human Research Program

- The Human Research Program (HRP) focuses on applied research
- Program goals
  - Perform research necessary to understand and reduce spaceflight human health and performance risks in support of exploration
  - Enable development of human spaceflight medical and human performance standards
  - Develop and validate technologies that serve to characterize and reduce medical risks associated with human spaceflight



An Applied Research Program


Radiation
Isolation & Confinement
Distance from Earth
Gravity fields
Environments

Human System Risk Summary – Risks by Hazard

Human Spaceflight Risks	Low Earth Orbit (Long) 30 D - 1 Y	Lunar Orbital (Short) < 30 D	Lunar Orbital (Long) 30 D - 1 Y	Lunar Orbital + Surface (Short) < 30 D	Lunar Orbital + Surface (Long) 30 D - 1 Y	Mars (Preparatory) < 1 Y	Mars (Planetary) 730-1224D
Radiation							
Non-Ionizing Radiation	A	A	A	A	A	AO	AO
Radiation Carcinogenesis **(LTH)**	RC	A	RC	A	RC	RM	RM
Distance from Earth							
Inadequate Human Systems Integration Architecture	A	RM/SR	RM/SR	RM	RM	RM	RM
Inflight Medical Conditions	A	A	RM	RM	RM	RM	RM
Inadequate Food and Nutrition	A	A	RM	A	RM	RM	RM
Ineffective or Toxic Medications	A	A	A	A	A	A	RM
Isolation and Confinement							
Cognitive or Behavioral Conditions	RM	AM	RM	RC	RM	RM	RM
Psychosocial Adaptation within a Team	AM	AM	RM	AM	AM	RM	RM
Altered Gravity							
Bone Fracture	A	A	RC	A	RC	RC	RC
Cardiac Rhythm Problems	AM	AM	AM	AM	AM	RM	RM
Concern of Venous Thromboembolism (VTE)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Host-Microorganism Interactions	AM	AM	AM	AM	AM	AM	RM
Orthostatic Intolerance	A	A	A	A	A	A	A
Reduced Aerobic Capacity	AM	AO	AO	AO	AO	AO	AO
Reduced Muscle Size	AM	AO	AM	AO	AO	AO	AO
Renal Stone Formation	A	A	A	A	A	RM	RM
SANS	A	A	A	A	A	A	RM
Sensorimotor Alterations	RM/SR	AM	RM/SR	RM/SR	RM/SR	RM/SR	RM/SR
Urinary Retention	A	A	A	A	A	A	A
Crew Egress	AM	RC	RC	RC	RC	RC	RC
Cardiovascular Adaptations	AM	A	AM	AO	AO	AM	RM
Hostile Closed Environment							
Altered Immune Response	AM	AM	AM	AM	RM	RM	RM
Carbon Dioxide Exposure	A	A	A	A	A	RM	RM
Celestial Dust Exposure	N/A	A	A	A	RM	N/A	TBD
Decompression Sickness	A	RM	RM	RM	RM	RM	RM
Dynamic Loads	AM	AM	AM	RM	RM	AM	RM
Electrical Shock	A	A	A	RC	RC	RC	RC
EVA Risk	A	AO	AO	RM	RM	AO	RM
Hearing Loss **(LTH)**	AM	AM	RC	AM	AM	RC	RC
Hypoxia **(LTH)**	RM	A	RM	A	RM	RM	RM
Sleep Loss	AO	AO	AO	AO	RM	RM	RM
Toxic Exposure	AM	AM	AM	AM	AM	AM	AM

Notes:

- Risk ratings are approved at the Human System Risk Board
- Risk ratings are for In-mission operations unless otherwise noted for Long-Term Health (LTH)
- Risk text color:
  - Current risk ratings
  - Risk ratings under review
  - Proposed to be approved
  - To be transferred to another risk
- Risk colors:
  - High LxC
  - Mid LxC
  - Low LxC
- Risk Dispositions
  A – Accepted
  AM – Accepted with monitoring
  AO – Accepted with optimization
  RM – Requires Mitigation
  RM/SR – Requires Mitigation/ Standard Refinement
  RC – Requires Characterization

National Aeronautics and Space Administration

HRP Standards, Technology and Countermeasures Deliverables

Human Research Program

BMed

1. Study Results for Biomarker Thresholds linked to Performance
   - Risk Characterization
   - Standards for Clinical guidelines
2. Standards for Treatments, CMs, and Tools
3. Risk Characterization for Key Indicators of Cognitive Performance & Behavioral Conditions

Space Radiation

1. Baseline Cancer PEL
2. Cancer PEL Update
3. Integrated Radiation CM Toolkit
4. Radiation Recommendations for Clinical Practice Guidelines
5. Radiation Countermeasure Identification
6. Recommendation for Fitness for Duty Standards

Food

1. Storage Limit Requirements
2. Physiological CM
3. System Trades and Validations

Team

1. CMs and Tools
2. Risk Characterization: Key Indicators Team Performance

CVD

1. CM based on Weightlessness
2. CM combined effects
3. Standards based on Weightlessness
4. Standards Combined Effects

ExMC

Medical

1. IMPACT Version 1.0
2. IMPACT Version 2.0
3. Foundation: Level of Care IV Long-Duration Lunar Orbital/Surface
4. Foundation: Level of Care V

Pharm

5. Exploration Formulary v3.0

HSIA

1. Integrated CM Suite
2. Risk Characterization for op performance metrics
3. Standards recommendations for just-in-time training
4. Standards update: HAB, HARI, Training, and HCI
5. Validated CMs

EVA

1. Injury Assessment Tool
2. Fitness for Duty Standards

Immune | MICRO

1. CM
2. Standards

Medical

1. Next Gen CHP Resource Scoping
2. Scoping Update

OP

1. Standards for Initial/Interim IARVs & protecting crew during dynamic phases of spaceflight
2. Standards for Validated IARVs & protecting crew during seated/ standing dynamic phases
3. Risk Characterization related to Lunar Landings

SANS

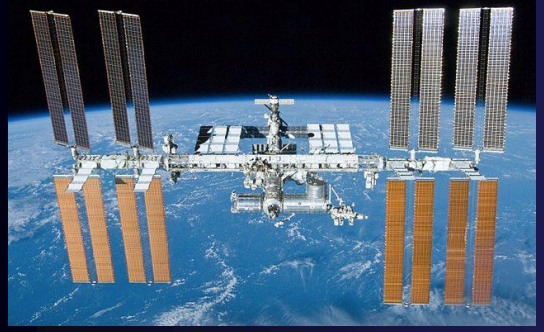
1. CM
2. Standards: Long Term Health
3. Standards: Maintaining inflight health

Sensorimotor

1. CM
2. Standards
3. Lunar CM
4. Lunar Standards

Venues for Conducting Research

International Space Station



Envihab

NSRL

Parabolic Flight

HERA

Antarctica

NEK

HRP Science Highlights

Solicitations

- 27 Grants for FY21
- 10 Directed Tasks

Artemis/Gateway

- Early Artemis Mission Payload – Artemis 2 Finalized. Artemis 3+ in work.

Significant Scientific Findings

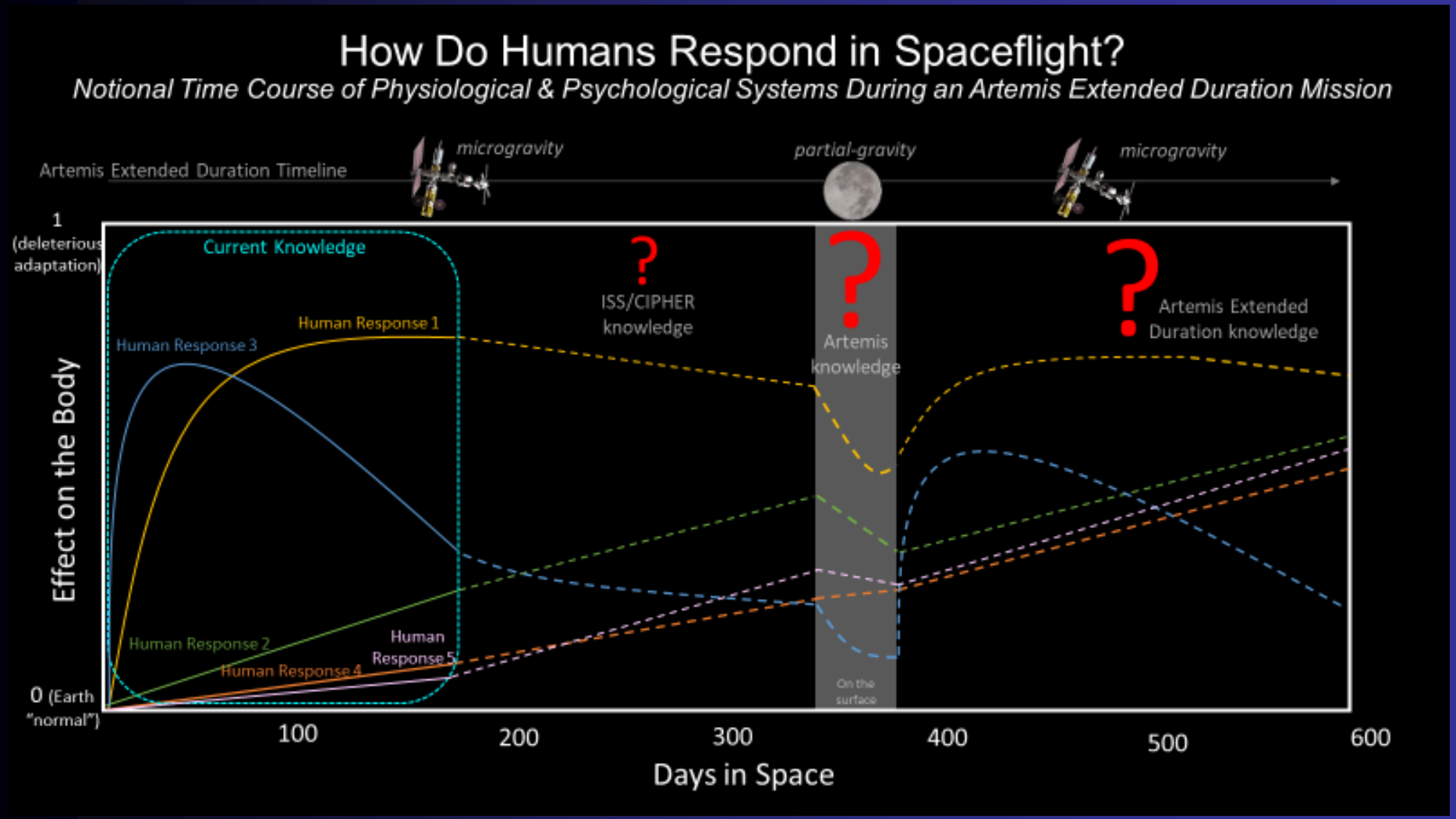
- Standard Measures - Collected on 12 ISS crewmembers (including 2 long-duration) and saw no noticeable changes in sleep duration, cognitive performance, and carotid intima-media thickness observed inflight compared to preflight.
- Venous Congestion Countermeasure Study (VCCM) – Identified Lower Body Negative Pressure device and thigh cuffs as candidate countermeasures to be tested in future analog and flight studies.
- Individual Level-Predictions Sleep and Performance Study - Provides simple method for predicting performance impairments due to acute and chronic sleep loss, and changes in circadian phase
- Skilled movement and posture deficits in rat string-pulling behavior following low dose space radiation (28Si) exposure – First demonstration of fine motor control changes post heavy ion exposure of the motor cortex (M1) as brain region sensitive to space radiation.

HRP IWS

- February 7-10 - All Virtual, Registration Free and Open

Translational Science

- HRP is more aggressively taking a multidisciplinary approach to addressing the identified risks and characterizing new and emerging risks
- Human Variability is large and our ‘n’ is small
  - Translating between individuals (population data and case studies)
  - Translating between populations (astronaut-like test subjects: HDBR; ICC; ICE)
  - Translating between species (rodent models for mechanistic studies): additional complexity of analogs (HLU)
- Time Course of exposure
  - Extrapolating out to different durations
  - Characterizing exposures: Galactic Cosmic Rays versus….


How Do Humans Respond in Spaceflight?
Notional Time Course of Physiological & Psychological Systems During an Artemis Extended Duration Mission
Artemis Extended Duration Timeline
microgravity
partial-gravity
microgravity
1 (deleterious adaptation)
0 (Earth "normal")
Effect on the Body
Current Knowledge
ISS/CIPHER knowledge
Artemis knowledge
Artemis Extended Duration knowledge
Human Response 1
Human Response 3
Human Response 2
Human Response 4
Human Response 5
On the surface
100
200
300
400
500
600
Days in Space

White Papers

- Nine Topical white papers submitted with HRP coordination
  - Spaceflight Food System: Impacts to Nutritional Adequacy, Health, Performance, and Resources in Space Exploration
  - Reverse Translation Strategies to Support Cognitive and Behavioral Risk Characterization
  - A Vision for the Next Generation of Spaceflight Microbiology: Human Health and Habitat Sustainability
  - Development of Medical Capabilities and Technologies for Health Monitoring, Diagnostics, and Treatment during Human Exploration Spaceflight
  - The Need for Biological Countermeasures to Mitigate the Risk of Space Radiation-Induced Carcinogenesis.
  - Enabling a Precision Health System for Deep Space Exploration
  - Development of a NASA Space Stressors Laboratory (NSSL) Leveraging Existing Resources
  - Recommendations for Spaceflight Research to Enable Crop Plant Growth 2 Systems for Exploration
  - Recommendations to Accelerate Translation of Animal Experimental Findings to Humans
- 65 unique co-authors

- Spaceflight Food System: Impacts to Nutritional Adequacy, Health, Performance, and Resources in Space Exploration
  - The food system is critical for crew health and performance, but it is a red risk for Mars. Research is required simultaneously in shelf stable foods, *in situ* food growth systems development, and in mass reduction technologies to ensure provisioning of adequate nutrients and variety. Research is also required to fundamentally understand the impacts of potential exploration food systems on all aspects of crew health and performance, from the immune system to brain function, which ultimately will impact mission success.
- Reverse Translation Strategies to Support Cognitive and Behavioral Risk Characterization
  - A coordinated suite of measurements to assess humans and animals needs to be established to support the translation and harmonization of animal research data to the astronaut corps due to the necessity of using animal subjects for radiation testing. The identification of POLs and PELs for spaceflight stressors (i.e. space radiation, altered gravity, isolation and confinement, sleep disruption) individually and combined will depend on defining scaling factors or transfer functions that can be used to relate human and animal outcomes.
- A Vision for the Next Generation of Spaceflight Microbiology: Human Health and Habitat Sustainability
  - A key objective for future human exploration missions is to understand and control the impact of the spaceflight environment on interactions between microbes, their hosts, and their habitat. The goal is to objectively understand and characterize a “new” spaceflight normal that reflects biological adaptation in this alternate environment. This knowledge will require integrated, multidisciplinary studies to advance our understanding of microbial responses to benefit human exploration missions through a myriad of possible biotechnological breakthroughs, including the design of synthetic biology and metabolic engineering approaches that enable the biosynthesis of diverse molecular compounds (*e.g.,* on-demand pharmaceuticals), food production and nutrient availability (*e.g.,* edible plants, pre-/probiotics, gut-brain strategies to maintain health), new methods for waste recovery, sustaining homeostasis of human, plant and environmental microbiomes, *in situ* resource utilization (*e.g.,* biomining, oxygen generation, carbon dioxide recovery), and planetary protection.

- Development of Medical Capabilities and Technologies for Health Monitoring, Diagnostics, and Treatment during Human Exploration Spaceflight
  - The next decade must see the development of new monitoring, diagnostic, treatment, and computational technologies supported by analog experimental data intended to fill these critical gaps. A significant challenge will be developing new technologies that elucidate, refine, and integrate large amounts of data from multiple sources among interrelated (and perhaps unrelated yet salient) systems and archetypes. These efforts will hinge upon our learning to more fully translate and integrate knowledge that considers and safeguards astronauts' short and long-term health and wellness while seeking to facilitate our future return and exploration of the Moon, and eventually, to Mars itself.
- The Need for Biological Countermeasures to Mitigate the Risk of Space Radiation-Induced Carcinogenesis.
  - Identification of medical countermeasures (MCM) that significantly reduce the risk of space radiation carcinogenesis is not only necessary, but imperative to enable long duration, deep space exploration, as well as to protect the long term health of human beings, as we become a space-faring species. Advancement of these approaches is essential to address a potential long duration, commercial and military human presence in space, in addition to NASA’s scientific and exploratory mission.
- Enabling a Precision Health System for Deep Space Exploration
  - Research and development efforts to enable a precision health system not only support future space exploration but could also offer solutions to similar challenges faced in terrestrial health care, particularly those in remote or isolated locations with existing limitations in health care systems. Much like the progression from information to knowledge through understanding and wisdom, a paradigm shift is required in our basic understanding of individualized spaceflight responses and ability to predict changes in health status during spaceflight. Finally, while certain aspects of precision health are currently employed by space medicine medical operations, a comprehensive and integrated precision health system would offer the best support of mission success by reducing risks, optimizing astronaut performance, and providing valuable insights into long-term astronaut health. Advancements in clinical decision making are important next steps in building dynamic individual risk profiles for astronauts and tailored countermeasure choices during deep space exploration.

- Development of a NASA Space Stressors Laboratory (NSSL) Leveraging Existing Resources
  - To capitalize on the unique ability of NSRL to simulate the space radiation environment and leverage available state-of-the-art specimen preparation resources, an expansion to the current capabilities is recommended to facilitate and accelerate integrated research on combined space hazards and risks including altered gravity, isolation/confinement, sleep and create a NASA Space Stressors Laboratory (NSSL).
- Recommendations for Spaceflight Research to Enable Crop Plant Growth 2 Systems for Exploration
  - Plant biology research in space has provided key insights into cellular and 2 molecular systems and their adaptation to microgravity. Continued understanding of the basic 3 function of plant systems in space will provide core knowledge essential for determining how 4 crop plants may, in the future, support a food and behavioral health system for planetary 5 missions. With the right level of support, NASA's Biological and Physical Sciences Division 6 (BPS), in partnership with the NASA Human Research Program and the NASA Systems 7 Capabilities Leadership Teams, can deliver evidence-based crop plant growth technologies and 8 approaches to enable future long-duration spaceflight missions to Mars.
- Recommendations to Accelerate Translation of Animal Experimental Findings to Humans
  - Substantial radiation research on the CV and BMed have established the foundation to accelerate future findings and conclusions. To build on past studies we recommend encouraging a comprehensive holistic experimental design approach that pairs human and animal (rodent to mini-pig) ground and spaceflight studies with standardized measures to utilize forward and reverse translation techniques with inclusion of clinically relevant functional endpoints, computational methods, & in-silico techniques when applicable.

Tissue Chip Joint Solicitation

Agency Partners

NASA

NIH National Institutes of Health

NIH National Center for Advancing Translational Sciences

NIH National Institute of Allergy and Infectious Diseases

NIH National Cancer Institute

BARDA

FDA U.S. FOOD & DRUG ADMINISTRATION

Extended Longevity of 3D Tissues and Microphysiological Systems for Modeling of Acute and Chronic Exposures to Stressors

NNH21ZDA015N NASA Research Announcement

- Lisa Carnell, PhD, Program Scientist, Biological and Physical Sciences Division (NASA)
- Steve Platts, PhD, Acting Chief Scientist, Human Research Program (NASA)
- Lucie Low, PhD, Scientific Program Manager, National Center for Advancing Translational Sciences (NIH/NCATS)
- Mary Homer, PhD, Chief, Radiological and Nuclear Countermeasures (BARDA)
- Shannon Loelius, PhD, Biologist, Radiological and Nuclear Countermeasures (BARDA)
- Jennifer Couch, PhD, Chief, NCI Structural Biology and Molecular Applications Branch, Division of Cancer Biology (NIH/NCI)
- Brian Sorg, PhD, Program Director, Division of Cancer Treatment and Diagnosis (NIH/NCI)
- Carmen Rios, PhD, Program Officer, Radiation and Nuclear Countermeasure Program, DAIT (NIH/NIAID)
- Halonna Kelly, PhD, Program Officer, Basic Immunology Branch, DAIT (NIH/NIAID)
- Tracy MacGill, PhD, Director, FDA Medical Countermeasure Regulatory Science, OCS, OCET

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Extended Longevity of 3D Tissues and Microphysiological Systems for Modeling of Acute and Chronic Exposures to Stressors

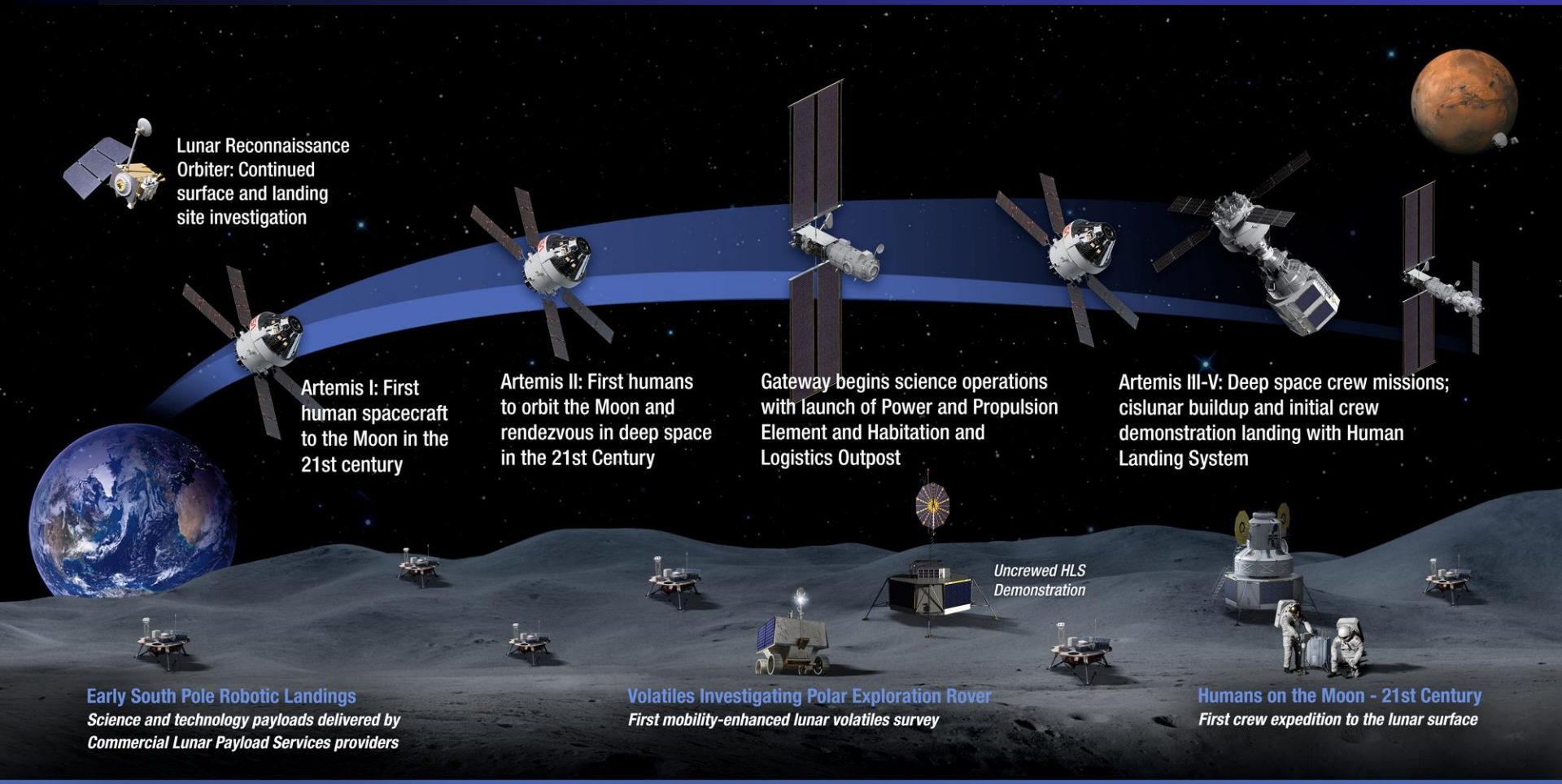
NNH21ZDA015N NASA Research Announcement

- NASA NRA focused on adapting existing 3D tissues and microphysiological systems (MPS), also known as "tissue chips" or "organs-on-chips"
- Primary goal: extend the current longevity of the 3D tissues and MPS to **at least 6 months**.
- Ground-based studies
- Awards issued from NASA as research contracts
- $500,000 total costs (direct plus indirect costs) per year for up to 4 years; $2M total per award
- NRA funding range expected $12 – $20M; anticipation 6-10+ contracts being awarded
- Certified Cost or Pricing Data may be required at the time of contract negotiation

National Aeronautics and Space Administration

Artemis: Landing Humans On the Moon

Human Research Program



LUNAR SOUTH POLE TARGET SITE

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National Aeronautics and Space Administration

HRP enabling Artemis missions

HRP solving problems for today's vehicle Programs.

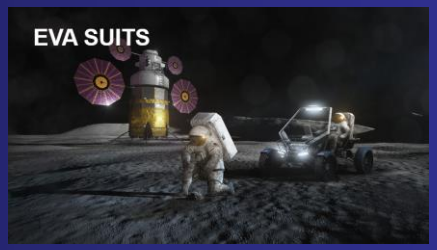
Human Research Program

- WMS requirements validation
- Cabin imagery system
- Flywheel exercise device collaborations

- Crew Health and Performance Integrated Data Architecture (CHP-IDA) – collaboration with AES/Enabling Capabilities

- Acceleration requirements
- Caloric requirements for high tempo EVA missions
- Autonomy Standards

- Acceleration/Vibration Requirements
- Autonomy Standards



- Emergency CO_2 limits
- In-suit Nutrition Requirements

- Food System Trade Study
- No-Treadmill ISS study Integration
- CHAPEA one year analog support and research collaborations

National Aeronautics and Space Administration

Artemis Utilization Planning

HRP Leading International complement planning for Human Life Sciences

Human Research Program

1. Dry Saliva Books
2. Crew/Team Perf. Measures
3. Actigraphy

1. Crew/Team Perf Measures
2. Actigraphy, Cognition, Sleep Questionnaires
3. Dry Saliva Books
4. Blood Analysis (TBD)
5. Ultrasound
6. Pharm Samples
7. Ophthalmic Measurements
8. IN-SITU (ESA/ASI led)
9. Thermosensor (ESA/DLR led)
10. TIME (ESA led)
11. EveryWear application (ESA/CNES led)

1. Ultrasound
2. Crew/Team Perf Measures
3. Actigraphy, Cognition, Sleep Questionnaires
4. Dry Saliva Book
5. Heart rate monitor
6. Alterations of Multi-Sensory Integration from Combined Hazards
7. Blood Analysis
8. Crew Health Data Mnmgt
9. Lunar Ascent/Descent Dyn Loads Injury Assess.

Thank you for Listening!

Questions?

Characteristics of HRP

- Composed of five Elements
  - Exploration Medical Capability
    - *Medical care for deep-space missions*
  - Human Factors and Behavioral Performance
    - *Interfaces between humans, vehicles & habitats*
    - *Individual and interpersonal*
  - Human Health Countermeasures
    - *Physiology*
  - Space Radiation
    - *Biological effects of radiation exposure*
  - Research Operations and Integration
    - *Infrastructure for flight and analog experiments*

- Funds Translational Research Institute for Space Health (TRISH) through cooperative agreement to pursue disruptive, breakthrough approaches that reduce risks to human health and performance
- Collaborates with NASA Space Biology to understand causal cellular and other mechanisms that underlie adaptation to fractional gravity levels in cells, microorganisms, plants, and animals

National Aeronautics and Space Administration

HRP Flight & Ground Analogs Facilities Status

Human Research Program

ISS Operations & Research:

- **Successful SpaceX** - First Ambient Sample Return from cargo flight on SpaceX-21.
- **Successful post-flight data collection for Crew-1** - First commercial crew landing with new logistics and processes to work out to support data collection. This flight returned the final subject for Vertebral Strength.
- **Axiom Research Planning** - Standard measures deferred to Ax-2.
- **CIPHER** - Preparation for 6-month campaigns progressing. First subject targeted for USCV-5.

Campaign 6: Four 45-day missions: 15 HRP studies (7 returning, 8 new)

- Primary campaign research themes - Human Systems Integration Architecture (HSIA) & autonomy.
- Current planning dates for crew ingress:
  - Mission 1: Oct. 1, 2021
  - Mission 2: NET late Jan. 2022
  - Mission 3: NET May 2022
  - Mission 4: NET late July 2022

SANS Countermeasure Bed Rest Study:

- Training and BDC began September 28.
- Study Start Oct 12, 2021 (first 2 subjects HDT)
- Campaign will consist of 6 HRP and 6 DLR investigations.

Winter-over 2021:

- Human Health Countermeasures (HHC) Palmer Immune Pilot study (Dr. Brian Crucian) conducting second winter-over data collection at Palmer station with planned completion of data collection mid-October.
- New Human Factors & Behavioral Performance (HFBP) Right Size Teams study (Dr. Noshir Contractor) implemented at McMurdo and South Pole stations between March and September 2021.

8- month NEK International/Multicultural Isolation Mission (SIRIUS 21): Nov 2021- April 2022

- 7 HRP studies from SIRIUS19 and one new HRP study selected for SIRIUS21.
- US prime and backup crewmembers started training and BDC in Moscow for the 8-month mission beginning of September.
- Ingress is planned for November 4, 2021.

Parabolic Flight:

- 6 HHC studies in planning with ESA focused on cardiovascular, sensorimotor and neurophysiological responses to 0 & partial g
- 0g study start with one 0g-only HRP study planned for October 17, 2021
- Combined partial g and 0g campaign for remaining HRP studies targeted for late calendar year 2022.

National Aeronautics and Space Administration

Coordinated Roadmaps across NASA

Integration of agency investments to reduce human health risks from Exploration Missions

Human Research Program

HEOMD Cross Cutting Deliverable
HEO Capability Gap Closure

Agency Investments in Human System Risk Mitigation

Habitation Systems Capability Leadership Team

Integrates among teams developing crew health & performance, environmental monitoring, and life support systems and develops agency-level roadmaps

CREW HEALTH and PERFORMANCE SYSTEMS

EVA Physiology | Counter-measures | Food + Nutrition | Radiation | Exploration Medical

Biological and Physical Sciences

Solicits and conducts research to understand how biological and physical systems respond to spaceflight environments, particularly reduced gravity and radiation

Human Research Program

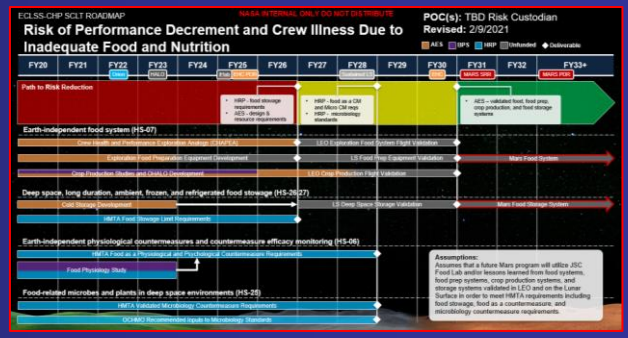
Enables human space exploration beyond LEO by reducing risks to astronaut health & performance through a focused program of applied research and technology development

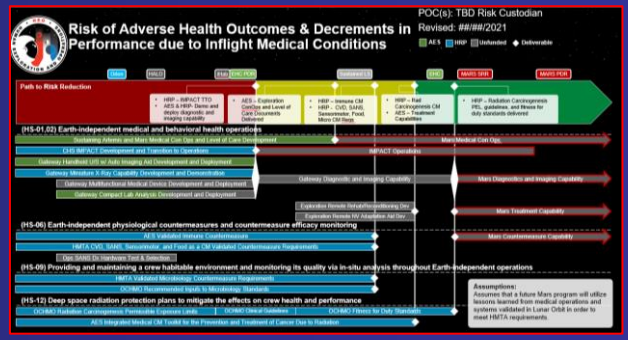
AES Enabling Capabilities

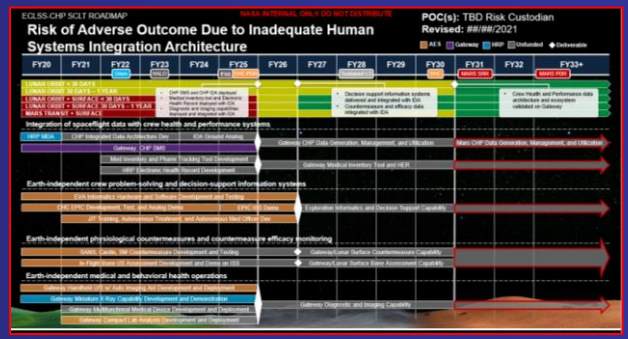
Develops prototype systems, advances key capabilities, and validates operational concepts for human missions outside of LEO

Crew Health & Safety

Provides a comprehensive astronaut occupational health program and agency capabilities for human health risk modeling and human health data collection, aggregation, and analysis

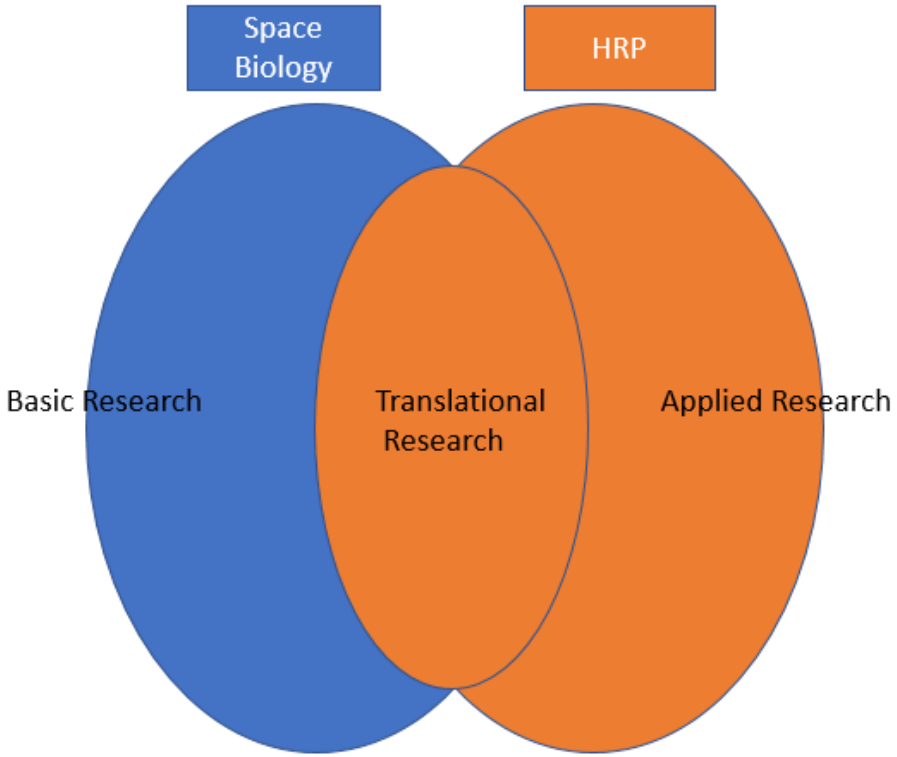






Integration across all Programs addressing Human System Risks

Overlap


Space Biology
HRP
Basic Research
Translational Research
Applied Research

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